



NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

**MARINE LIGHT ATTACK HELICOPTER CLOSE AIR
SUPPORT TRAINER FOR SITUATION AWARENESS**

by

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June 2017

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REPORT DOCUMENTATION PAGE			<i>Form Approved OMB No. 0704-0188</i>	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE June 2017		3. REPORT TYPE AND DATES COVERED Master's thesis
4. TITLE AND SUBTITLE MARINE LIGHT ATTACK HELICOPTER CLOSE AIR SUPPORT TRAINER FOR SITUATION AWARENESS			5. FUNDING NUMBERS	
6. AUTHOR(S) John F. Gibson				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB number NPS.2017.0043.				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release. Distribution is unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (maximum 200 words) <p>In today's dynamic combat environment, the importance of Close Air Support (CAS) has increased significantly due to a greater need to avoid civilian casualties and fratricide while maintaining effective fire support for engaged friendly forces. Situation awareness (SA) is a skill that is extremely important in conducting CAS safely and effectively, and is frequently one of the greatest deficiencies of new pilots. As budgets shrink and throughput on current training solutions remains very low, it is difficult to provide new CAS aviators with the number of training repetitions needed to gain SA proficiency. A tablet computer-based CAS part task trainer (PTT) to improve SA was developed to address this. This system provides the visual and audio stimuli of the CAS battlefield and trains a new pilot to observe the environment, listen to communications, comprehend what is happening, and make timely inputs based on his or her understanding of the overall situation. Throughout the training, the system provides questions to the student to evaluate the student's level of SA and to emphasize key SA elements. The lessons delivered by the prototype CAS PTT suggest that it will be useful to teach CAS situation awareness and improving the performance of new pilots. Continued development of a series of low-cost part task trainers that fill different training gaps could result in significant improvement in training future generations of aviators.</p>				
14. SUBJECT TERMS close air support, part task trainer, commercial-off-the-shelf systems, situation awareness, tablet-based training solution, virtual environment			15. NUMBER OF PAGES 87	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UU	

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**MARINE LIGHT ATTACK HELICOPTER CLOSE AIR SUPPORT TRAINER
FOR SITUATION AWARENESS**

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Submitted in partial fulfillment of the
requirements for the degree of

**MASTER OF SCIENCE IN
MODELING, VIRTUAL ENVIRONMENTS, AND SIMULATION**

from the

**NAVAL POSTGRADUATE SCHOOL
June 2017**

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ABSTRACT

In today's dynamic combat environment, the importance of Close Air Support (CAS) has increased significantly due to a greater need to avoid civilian casualties and fratricide while maintaining effective fire support for engaged friendly forces. Situation awareness (SA) is a skill that is extremely important in conducting CAS safely and effectively, and is frequently one of the greatest deficiencies of new pilots. As budgets shrink and throughput on current training solutions remains very low, it is difficult to provide new CAS aviators with the number of training repetitions needed to gain SA proficiency. A tablet computer-based CAS part task trainer (PTT) to improve SA was developed to address this. This system provides the visual and audio stimuli of the CAS battlefield and trains a new pilot to observe the environment, listen to communications, comprehend what is happening, and make timely inputs based on his or her understanding of the overall situation. Throughout the training, the system provides questions to the student to evaluate the student's level of SA and to emphasize key SA elements. The lessons delivered by the prototype CAS PTT suggest that it will be useful to teach CAS situation awareness and improve the performance of new pilots. Continued development of a series of low-cost part task trainers that fill different training gaps could result in significant improvement in training future generations of aviators.

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LIST OF ACRONYMS AND ABBREVIATIONS

2D	Two Dimensional
3D	Three Dimensional
AAR	After-Action Reviews
ACM	Airspace Coordination Measures
AR	Armed Reconnaissance
ATS	Aviation Training Systems
BP	Battle Position
CAS	Close Air Support
CJCS	Chairman of the Joint Chiefs of Staff
COTS	Commercial off the Shelf
CDU	Communication Data Unit
DASC	Direct Air Support Center
DOD	Department of Defense
DON	Department of the Navy
FAC	Forward Air Controller
FAC(A)	Forward Air Controller (Airborne)
FAH	Final Attack Heading
FOV	Field of View
FP	Firing Point
FPS	Frames per Second
FSCM	Fire Support Control Measure
FW	Fixed Wing
GP	Gun Position
GTL	Gun Target Line
GUI	Graphic User Interface
HA	Holding Area
HMLA	Helicopter Marine Light Attack
IDE	Integrated Development Environment
IP	Instructor Pilot
IRB	Institutional Review Board

ITX	Integrated Training Exercises
IUT	Instructor Under Training
JFIRE	Joint Application of Firepower
JSON	JavaScript Object Notation
JTAC	Joint Terminal Attack Controller
MAGTF	Marine Air Ground Task Force
MATSS	Marine Aviation Training System Sites
MAW	Marine Aircraft Wing
MAWTS	Marine Aviation Weapons and Tactics Squadron
MCWP	Marine Corps Warfighting Publication
METL	Mission Essential Task List
MIM	Military Installation Map
NTTP	Naval Tactics, Techniques, and Procedures
OAD	Objective Area Diagram
OAS	Offensive Air Support
PTT	Part Task Trainer
PUI	Pilot Under Instruction
ROE	Rules of Engagement
RW	Rotary Wing
SA	Situation Awareness
SAM	Surface to Air Missile
SME	Subject Matter Experts
T&R	Training and Readiness
TEFACHR	Threat, Enemy Situation, Friendly Update, Artillery, Clearance Authority, Hazards, And Remarks/Restrictions
TOT	Time On Target
TTPs	Tactics, Techniques, and Procedures
USMC	United States Marine Corps
VE	Virtual Environment
VR	Virtual Reality
WTI	Weapons and Tactics Instructor

ACKNOWLEDGMENTS

I want to thank the following individuals:

My wife and daughter for their support and unwavering commitment throughout this project.

Dr. Amela Sadagic for her assistance and guidance to see this thesis work through.

Michael Guerrero for teaching me how to use Unity.

The Office of Naval Research for the computing equipment provided to build the Close Air Support Part Task Trainer.

Major Jesse Attig for having the vision to initiate and design the Close Air Support Part Task Trainer.

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I. INTRODUCTION

A. RESEARCH DOMAIN

Marine Corps aviation differs from other service aviation forces in that it is designed to operate as part of an integrated combined-arms task force instead of a separate maneuver element (Department of the Navy 2000, 1–1). This combined-arms task force is referred to as the Marine Air Ground Task Force (MAGTF). As part of this integrated force, aviation assets bolster the Marine Corps ground forces' limited surface fire support assets. One of the direct air support missions that MAGTF aviation provides for ground forces is close air support (CAS). CAS is the direct fire support to ground forces and is integrated with the ground forces' scheme of maneuver:

Close air support (CAS) is air action by fixed-wing and rotary-wing aircraft against hostile targets that are in close proximity to friendly forces, and requires detailed integration of each air mission with the fire and movement of those forces. (Chairman of the Joint Chiefs of Staff (CJCS) 2003, I-1)

The CAS environment is dynamic, difficult, and demanding, and it is filled with a great deal of friction and confusion.

CAS is one of the core elements on the Marine Light Attack Helicopter (HMLA) Squadron's Mission Essential Task List (METL), meaning it is a primary mission that the HMLA was designed to perform (Department of the Navy 2014, 1–7). HMLA pilots must be well trained to handle the demands of CAS to execute the HMLA's mission successfully. With the rules of engagement (ROE) of recent conflicts, CAS is becoming more important to all services, as the risk of collateral damage from indirect fires has made CAS the preferred type of fire support to ground maneuver elements. The importance of CAS to the MAGTF is tremendous and the training of young HMLA pilots to provide effective CAS to the MAGTF is of the highest priority. Hence, the initial training phase for new HMLA pilots is a crucial in developing competent CAS proficient aviators, and

due to this, HMLA instructor pilots are always looking for advances to improve early CAS training.

As warfare has evolved, so has the tools used to conduct CAS evolved. Early CAS was conducted by releasing ballistically guided ordnance with a controller on the ground using a map and radio guiding the pilot where to shoot. Today, CAS uses not only ballistically guided ordnance, but also laser and GPS guided weapons as well. The ground control team now utilizes laser designators, laser range finders, GPS, advanced optical sensors, and computers to acquire and pass information and targets to CAS aircraft. This information is often sent between the aircraft and ground controller digitally as well as via voice over radio communications. The wealth of information available today greatly enhances CAS operations by increasing the accuracy of ordnance and reducing fratricide.

B. RESEARCH PROBLEM

CAS has come a long way from the days of a controller telling a pilot to drop a bomb on a smoke marker next to a target to the current tactics of a missile following laser energy from a designator to the exact desired point of impact on a target. With the advancement in CAS techniques, aircraft and training facilities have improved too. Instrumented ranges gather precise data on marksmanship accuracy on targets and simulated surface to air missiles (SAM) called “smoky SAMs” actually fire small Styrofoam model rockets for aircraft to evade. Even modern simulators create such a high fidelity environment with state of the art visuals that pilots feel as if they are in the aircraft flying real missions. Sophisticated sensors record aircraft positioning and all communications, and that type of information allows for high quality playback during debriefs. However, CAS ground training for pilots has advanced little with technology. Pilots still get the majority of their CAS ground training by reading printed publications; another alternative is a face-to-face discussion on procedures with an instructor. If computer-based training is offered, it is usually in the form of a PowerPoint slide show.

Much aviation training teaches pilots to execute correct procedures such as completing checklists, takeoff and landing, operating aircraft systems and talking on the radios. CAS requires more than just procedural knowledge though. A CAS pilot must understand what is happening around them and how to act in accordance with these events. To conduct CAS effectively, the pilot must not only execute correct CAS procedures and communications, but the pilot must also track friendly and enemy unit locations and when ordnance is being employed. Maintaining the constant awareness of all of these items places a heavy load on working memory and attention situation awareness (SA) (Endsley 2000, 12). The situation awareness (SA) that a pilot must maintain is defined by Endsley (1995) as “the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future” (65).

Typical space requirements in the CAS environment are items like unit positions and locations where rounds impact. While know when to shoot is a time requirement. A pilot must comprehend what these mean, and use that knowledge to project what will happen; both actions show just how important SA is to CAS. There has been a concerted effort to make technological improvements to CAS procedures and systems that improve CAS participant’s SA such as precise target marking and digitally transmitted information flow, but little has been done to improve the ground training for aircrew and to augment the acquisition of good situation awareness.

How to acquire that better SA is a question frequently asked and studied in many aviation and combat arenas (Kass, Herschler, and Companion 1991, 105). A survey of the research that was done on that subject suggests that people who perform with high levels of SA are able to match patterns recognized in current situations and compare them with those from previous experiences, and make decisions from this information (Endsley 2000, 16). While much of this experience is gained through real-world situations, it can be learned through training in simulated environments as well (Kass, Herschler, and Companion

1991, 110). Kass, Herschler, and Companion conducted a study using a tank simulation to demonstrate if seeing and recognizing patterns during training created an experience that learners could adapt to other similar situations. Their purpose was to determine if the learner could transition from learning procedural knowledge to a skill-based learning through pattern recognition. The results of their study indicated that learners experiencing training focused on proper battlefield cues did gain improved pattern recognition ability and thus higher SA.

Based on the finding that subjects did better in an armor battle after receiving situation awareness training using a simulated battlefield, it is very likely that pilots will receive similar benefit from a simulated CAS scenario that provides environment stimulating situation awareness (Kass, Herschler, and Companion 1991, 110). If pilots can connect simulated environmental features to real world ones and create long term memory models that reduce working memory requirements it could possibly lead to improved performance in the aircraft during actual CAS missions (Endsley 2000, 13). Bundling this training into a part task trainer may give the pilot a new tool that improves their SA.

C. RESEARCH QUESTIONS

The following research questions have been identified in support of the research effort described in this thesis:

- What is the feasibility of developing a tablet or laptop based virtual environment (VE) part task trainer (PTT) aimed at improving new HMLA pilot's situation awareness for close air support (CAS) missions in the aircraft?
- What is the feasibility of using immersive VE technology in support of training of situation awareness?
- What is the overall user experience and usability (effectiveness, efficiency and user satisfaction) of the final user interface?

D. SCOPE

The scope of this thesis is to expand upon research work on a proof of concept helicopter CAS part task trainer (Attig 2016) into a prototype that not

only supports training of procedures and communications (like the original prototype) but it also adds the concerns of situation awareness training during CAS missions for junior HMLA copilots. The resulting PTT simulates the CAS battlefield environment and pilots are able to gather situation information from the scenario presented to them in simulation. The subject pilots will then be tested on his (her) ability to correctly understand the situation. The capabilities of the final PTT interface will be also tested in a formal usability study; this will allow us to test select elements of trainees' experience and gain more information about their ability to execute scenario presented in PTT and their satisfaction with the interface.

E. APPROACH

This research effort expands on the present HMLA CAS PTT by analyzing current HMLA instructor pilots' situation-awareness training techniques and implementing those techniques into the PTT's simulated virtual environment. This study expands the CAS mission task analysis by Major Jesse Attig (Attig 2016) adding details relevant to situation awareness for all steps before and during the attack. Additionally, the study analyzes the users' ability to process audio information for details about his or her environment and then answer questions to demonstrate how well the user's perception mirrors reality.

Also, this study attempts to create a user interface that allows intuitive and expedient input of all information required to create an effective CAS training scenario. A feasibility study was designed to determine if the incorporated visual and auditory cues needed to support situation awareness are included in the PTT. The results of this study will be used to create the structure for a future study using CAS trained pilots to provide feedback on system usability.

F. THESIS STRUCTURE

The remaining chapters are summarized as follows:

Chapter II reviews and discusses current CAS ground training and the current capabilities of the proof of concept HMLA CAS part task trainer.

Chapter III discusses current situation awareness training and measurement techniques.

Chapter IV provides a detailed task analysis on the use of the PTT to generate and execute a CAS scenario for SA training.

Chapter V details the development of the training system situation awareness elements, the methods used to measure those skills, the user interface improvement development, and the design of training scenario inputs and audio enhancement.

Chapter VI provides details of the feasibility study, including the test of system performance and usability study conducted with domain users.

Chapter VII presents the results and conclusions of the work, and lays out the most promising avenues for the future work.

II. BACKGROUND

A. INTRODUCTION

New HMLA pilots show up to an operational fleet squadron after they have been qualified to fly their aircraft and operate the aircraft systems. However, at that point they have received little close air support training. The new pilots are familiar with a non-tactical flight environment that except for ordnance delivery, as well as some tactical maneuvering that is not much different from a civilian flying environment. Within six months, these pilots must become combat ready (CR) copilot. One of the areas they must become proficient in is CAS.

Attaining combat readiness in CAS requires extensive knowledge of procedures and communications. Pilots must also become familiar with the environment and be able to perceive and understand the CAS battlespace environment, and be ready to act in it. Currently, CAS training for pilots begins with ground training. That training segment consists of readings in standardized publications, followed by instructor pilot (IP) led discussion sessions, and culminating in walk-through exercises. This will be the only CAS training before the pilot steps into the simulator for the first syllabus CAS event.

B. PROBLEM SPACE

After every CAS training mission, the HMLA aircrew that just flew the mission will meet and debrief the flight in ready room. In this debrief, the situation awareness will more than likely be one of the topics of discussion, especially if one of the pilots was a junior aviator flying one of the H-1 helicopter's syllabus initial CAS training events. Many of the debrief items concerning the flight will probably be about the lack of SA or the loss of SA during the mission. There is good reason for this issue to be emphasized: previous studies have shown that poor or incorrect SA were found to be a leading cause of military aviation mishaps (Endsley and Garland 2000, 2–357) and a frequent cause of fratricide in CAS (Rafferty, Stanton, and Walker 2012, 24).

The doctrinal CAS manual, Department of Defense Joint Publication 3–09.3 lists “thoroughly trained personnel with well-developed skills” at the top of its list of conditions for effective CAS (CJCS 2009, I-7). Extensive training is crucial because the pilots must have many repetitions and gain considerable experience before they are ready to conduct a real world CAS mission. Most of this training will take place in the aircraft and in full aircraft simulators; this is where pilots gain most of their experience. However, as budgets shrink the flight hours are becoming harder to get and the simulators are becoming more crowded. This creates throughput issues reducing the capacity to train pilots, so accomplishing some of that training prior to stepping in the simulator or aircraft is crucial.

C. CURRENT TRAINING

A new pilot will begin CAS training by reading assigned portions of publications including the JP 3–09.3 Close Air Support for a broad view of all regulations, procedures and purposes of CAS, and the NTTP 3–22.3-UH1 for HMLA specific CAS techniques, tactics and procedures. This will be followed by series of five CAS lectures and two “chalk talks” (United States Marine Corps 2011). All of these events are to be led by an instructor pilot. The lectures will be in typical lecture format with the focus on procedures and techniques. The “chalk talks” will be interactive with an IP leading the discussion.

The first “chalk talk” is titled “CAS discussion and walkthrough demo” and the second is “H-1 CAS TTPs” (United States Marine Corps 2011). The former is first chance the pilot under instruction (PUI) views the dynamic nature of the CAS environment in an interactive setting. Instructor pilots and other CAS qualified pilots will play various CAS roles in a walk-through format. Usually, a large drawing of the CAS objective area map is laid out on the ground in chalk and the role players are stationed at locations on the map representing where they would be in the real world. The lead instructor directs the role players through the events of CAS scenario and drives the development of the scenario. The role players will simulate the procedures and radio communications that would take

place while the IP explains the events to the students. Each role player will verbalize each radio call and walk a path across the objective area map representing the flight or ground path of the actual entity to build the situation for the PUI.

The training that PUIs are exposed to focuses not only on the CAS procedures, but also on all events that take place, as well as events that trigger follow on events. The IP should draw the student's attention to what communications and events trigger follow on events during the course of the "chalk talk." For instance, when pilot hears that an aircraft is departing its holding area to begin an attack, the pilot should know where to look in the sky to see that aircraft as it maneuver—this is important so that pilot's own actions do not interfere with that aircraft. Also, based on that departure time the pilot will know if that aircraft will meet its time on target and how that might affect his follow on attack. This is the beginning of the development of a pilot's situation awareness for CAS. This initial CAS SA ground training is the only specified syllabus ground training event that really demonstrates and teaches CAS SA.

A new pilot may get a higher number of these CAS walk-through "chalk talk" repetitions if an IP is available to lead one. Sometimes a group of junior pilots will get together and conduct their own walk through, but they will be required to instruct themselves without any oversight to ensure that procedures are correct and that the training session is beneficial. Adding a PTT as an additional training solution equipped with standardized scenarios and evaluation, would greatly benefit the CAS ground training of new HMLA pilots and set them up to be better prepared for their first CAS flight.

D. INFLUENCES ON DESIGN: CANDIDATE SOLUTIONS

Major Jesse Attig recognized this gap in the CAS training of HMLA aviators (Attig 2016). He designed a proof of concept part task trainer (PTT) for Close Air Support operations; this was a step in the direction to fill the gap in CAS ground training. This trainer makes use of an interactive virtual environment

that takes a pilot from launch to beginning of a CAS attack. The user (pilot) is presented with a scenario and he (she) must answer various preloaded questions that pop up along a simulated flight route. The pilot is expected to focus training on the procedures and the communications associated with CAS.

Along with executing correct procedures and communications, an aviator conducting CAS must also keep track of the current location of friendly ground and air forces, where they are moving to, where the targets are, when and when supporting arms are firing, and when and where bombs are being dropped. A good understanding of all those elements will ensure that the pilot will be able to operate effectively. Maintaining a constant awareness of all of these items places a heavy load on working memory and attention (Endsley 2000, 12). A pilot must maintain situation awareness including an accurate perception of time and space (Endsley 1995, 65). For instance, those elements will include space requirements such as the enemy and friendly positions, positions where units are firing, and time requirements like when units fire or drop ordnance. A pilot must comprehend what these mean and use that to project what will happen next showing just how important SA is to CAS.

How to acquire better SA is a question frequently asked and studied among the researchers and practitioners in this domain. Most SA comes from input to the five senses (Endsley 2000, 9). For CAS operations, the visual and aural domains are the two primary senses receiving cues relevant to the CAS mission. Tactile and olfactory senses play a part, but stimulus to those senses is generally more relevant to aircraft performance not CAS. Therefore, the SA training system should provide visual and audio cues relevant to the CAS environment. Also, the PTT should present information to the user that is similar to the real environment.

The HMLA PTT was developed to help remedy the gap in pilot knowledge by teaching pilots CAS procedures (Attig 2016). Procedures are the foundation of effective CAS, but there is a great deal of flexibility required in executing those procedures. Retired U.S. Air Force Major General I.B. Holley states that there is

“no prescription...to be followed slavishly and mechanically” when conducting CAS, and those procedures “must sometimes be altered or adjusted to fit these local variations” (Cooling 1990, 535). In order to know when a pilot must make adjustments, the pilot needs to understand what is happening in the environment, and be able to make decisions on how to properly affect the outcome. Endsley determined these skills to be situation awareness (Endsley 1995, 65). Pilots gain this skill through the experience gained in training. In the past, most of this training was accomplished through flying CAS training missions in the aircraft. However, with the reduction of available flight hours looming ahead there must be alternative mean to achieve proficiency quickly. The goal for this study is to use a virtual environment that simulates visual and audio sensory experiences of a CAS environment, and allow junior HMLA pilots to train CAS operations and improve situation awareness skills prior to climbing into the aircraft for their first mission.

Attig surveyed HMLA instructor pilots (IP) and pilots under instruction (PUI) on what were the top three CAS difficulties for PUIs, and the results were that both groups listed situation awareness as the second most important difficulty area (Attig 2016). This consensus amongst instructor and student highlights the importance of SA in CAS missions. Situation awareness is also a graded part of the flight event as well. By the end of the CAS training flights, PUIs must be able to utilize CAS procedures and communications correctly and recognize and correct their own errors with only occasional input from the IP. This is according to the official grading criteria per the official USMC Aviation Tracking Form derived from the H-1 Training and Readiness (T&R) Manuals (Department of the Navy 2014, 1–6). In the survey to the IPs, the instructors were asked if they though the PUIs were able to recognize and correct mistakes without IP input. The IPs responded that the majority of PUI could not do this.

Based on these results and potentially severe consequences of having incorrect SA during a CAS mission, it can be concluded that it is imperative for PUIs to receive additional training to improve their SA. For many years, gaining

SA was accomplished only through experience from performing the actual task (Endsley 2000, 3). Most of that experience for HMLA pilots comes from flying CAS training missions. In today's fiscally strained environment it is difficult for a squadron to fly the amount of flight hours to get pilots the experience required to perform at a high SA level. Increased ground training or simulator training are the only options available, but even simulator time is hard to come by with so many pilots needing trained. That leaves ground training as the only viable option. Unfortunately, the only real method that includes any situation awareness teaching has been the IP led discussions or "walk-throughs."

This method requires considerable time to set up and the availability of an instructor to conduct the training. With advancements in technology, SA training should be able to immerse the PUI in a digital virtual environment that simulates the CAS mission environment. The virtual training environment must be both expedient for the instructor to set up and easily and quickly accessible for the student to utilize. This virtual environment can then provide some of the elements to train SA that a PUI would only receive from flying actual CAS training flights in the past.

An additional consideration needs to be proven: it must be determined if the tasks required to measure SA are the types of tasks that can be learned effectively in a virtual environment. Immersion and interactivity are important for the PTT VE (Stanney, Morurant, and Kennedy 1998, 333), but the measurement of PUI success will be gauged from the scoring of the SA questions they answer. Even though the PTT as implemented by Attig (Attig 2016) is not a high fidelity VE, we believe it should be capable of improving the SA. An additional argument that supports this understanding is a study by John et al. (John et al. 2015, 156). This study found that users of a surgical application presented on a tablet computer experienced positive effects performing cognitive tasks, even though the application was considered a low fidelity simulation. Also, the research by Endsley (2000) found that cognitive processes were very important in acquiring and maintaining SA.

A PTT could therefore provide the environment that builds a mental model of the CAS battlefield for a new pilot while enabling the training of procedures. Endsley surmises these mental models can help form long-term memory structures for the pilots, which can be recalled at a future time and help with situation recognition and decision-making (Rouse & Morris 1985, 27). These mental models could allow the pilot to recognize situations and then use that long-term memory to make appropriate timely decision (Endsley 2001, 7).

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III. SITUATION AWARENESS TRAINING AND MEASUREMENT

A. INTRODUCTION

The previous chapters defined situation awareness, explained its importance, and surmised that a tablet based part task trainer would be a good platform to host CAS SA training. Before implementing this PTT, we must identify what is needed to train CAS situation awareness to new pilots and the best way to measure how effective the SA training was after it is complete. Former Chief Scientist for the U.S. Air Force and President of SA Technologies, Dr. Mica Endsley, has dedicated several decades to studying situation awareness including training and evaluating SA; much of that work was focused on military aviation and tactical environments. We used many of her findings to inform the design of the CAS PTT that would train and evaluate situation awareness.

B. WHAT IS NEEDED TO TRAIN SA?

One of the first tasks in determining what is needed to train SA is deciding what types of requirements are related to situation awareness. Situation awareness requires more dynamic knowledge than traditional static knowledge job requirements. Situation awareness has goal oriented objectives that require a level of understanding followed by a decision making process to achieve that goal. Whereas, static jobs require more following rules and procedures to complete tasks. (Endsley 2001, 8). These static tasks frequently instruct the user to do one thing then another in a certain order or repeat rote knowledge. Dynamic tasks give a goal state then require the user to interpret information and make decisions in order to achieve that goal rather than just follow a set of instructions. Endsley uses a goal driven task analysis format, which is depicted in Table 1.

Table 1. Format of Goal-Directed Task Analysis.
Source: Endsley (2001).

Goal
Subgoal
Decision
Projection (SA Level 3)
Comprehension (SA Level 2)
Data (SA Level 1)

Per Endsley's definition, SA level 1 is how the subject perceives the elements of the environment. SA level 2 is what the subjects comprehension of the environment is, and SA level 3 is how the subject can interpret what he (she) comprehends and projects what the future outcome will be (Endsley 2001, 4). A modified version of this concept will be used to determine what our system needs to train with regard to SA.

The overall goal of this trainer is to teach the situation awareness items that are important for safe and effective CAS. Subgoals needed to support this would be the items such as getting ordnance effects on the target and not on friendly forces (friendlies). Knowing where the enemy and friendlies are relative to the attacking aircraft is needed to make a decision and accomplish this subgoal. Since the training audience for this trainer consists of new pilots, the emphasis will be on training the SA level 1 and 2 only. New pilots need to have CAS environmental elements presented to them and then understand those elements in the environmental context rather than repeat static knowledge items. Situation awareness accumulates over the course of a mission and it is therefore important to determine what elements are relevant to the pilot. The pilot has to prioritize the information and then use it to make decisions based on projections of the near future (Endsley 1988, 791). Even though the focus of this trainer is the lower levels of SA, the situations presented in it and experiences of the pilots will provide a foundation for more advanced SA functions. In the PTT, the pilot

will be provided with a variety of environmental elements that are characteristic of the CAS battlespace.

There is no evidence of any direct guidance on what environmental elements the United States military includes in situation awareness for close air support. However, connecting the link between situation awareness and risk assessment there are parallels that give indirect guidance on important elements. Former Ohio State University Department of Aviation Professor Richard Jensen linked what he termed aeronautical decision making or aviation judgment to SA (Jensen 1997, 262). He stated that better aeronautical decision-making leads to better SA and listed five main factors of expert aviation judgment. Three of those have a direct impact on situation awareness: attention control, dynamic problem solving, and risk management. Attention control and dynamic problem solving are straightforward. Keep focused and solve problems in the ever changing flight environment, but a key part of the problem solving includes being able to use time critical pattern matching to make crucial decisions. This is very similar to the pattern matching in situation awareness (Endsley 2000, 6).

Yet according to Jensen's definition, risk management is the most similar to situation awareness (Jensen 1997, 264). He explains, "Risk management means being aware of the risks in all flying situations and being able to assess them" and "ranking them least risky to most risky." He also adds, "Risk assessment requires knowledge and SA." Being aware of the situation or environment, being to comprehend or assess the elements, and prioritize them in order to make future decisions is very close parallel to Endsley's view on SA (Endsley 1988, 791).

Drawing this parallel between SA and risk assessment, we find a list that gives us guidance to what elements to include in the trainer. The Joint CAS publication presents a tactical risk assessment in the CAS execution chapter (CJCS 2003, V-18). It states as the battlefield environment changes CAS terminal controllers and aviators must make continuous risk assessments. In those assessments, they should consider time, information flow and

communications, tracking of battlefield entities both friend and foe, threat information, and target information including marking. These items will form the basis of our elements for inclusion in the trainer environment. The elements needed to create the CAS trainer can be divided into three categories: elements and events related directly to CAS execution, elements pertinent to the CAS environment inside the aircraft, and environmental elements outside the aircraft.

The initial environment elements included in the trainer are those relating directly to the CAS execution. These physical elements consist of the target, the anti-aircraft threat, the friendly ground unit, supporting arms and the terminal controller. The informational elements are the route of flight, the friendly / enemy situation update, the CAS attack brief, target mark, and clearance to fire. The CAS terminal controller, the person on the ground directing the CAS aircraft where to go and when and where to shoot, communicates the informational elements which include details about the physical elements to the pilot. All of the elements other than marking the target for identification are generally conveyed to the pilot via radio communication. The target mark can be an audio or visual cue. For this training scenario, we will use the visual cue, as that is the most common for CAS missions.

The next set of elements will be the tools that pilot uses in the cockpit of the aircraft to conduct CAS. The items a pilot utilizes in the aircraft when conducting a CAS mission, minus weapon systems and electro-optical sensors, were selected for representation in the trainer. These items are a moving map display, a compass heading indicator, a timer, and radio communications. Aircraft frequently have electro-optical sensors that can enhance situation awareness, but these systems were omitted because they are not needed to teach basic CAS SA fundamentals. Weapons systems were omitted since ordnance delivery does not directly affect SA.

Finally, the trainer will create ambient environmental elements. These elements were limited the few items required to create a virtual environment. The terrain is simulated to create a realistic visual flight environment. Rotor noise is

included to further increase the realism as it represents an ever-present background noise distraction that pilots would expect to hear in an operational environment. The firing of artillery and the firing aircraft ordnance are also included to confirm the points in time when these events take place.

After determining what elements were to be included in the trainer, the next task focused on the form in which they would be presented to the PUI. Based on the analysis of CAS missions and example mission flows from the Joint CAS publication and the Marine Aviation Weapons and Tactics Squadron 1 (MAWTS-1), it was determined that a large amount of the SA building information comes from radio communications that take place during a normal CAS mission flow (CJCS 2009, V-22) (United States Marine Corps 2013). The PTT uses the normal flow of CAS radio communications between the terminal controller and the pilot to provide the majority of essential spatial and time information for the PUI. Information such as the location of battlefield entities, direction of fire, and time for events were passed to the pilot in this manner. The pilot needs to retain this information with the same time constraints just as if he or she was in the aircraft conducting a CAS mission. The visual elements are used primarily for orientation such as knowing if the aircraft is on the correct heading based looking at the simulated terrain, the map, and the heading indicator. Also, the target marks used by the PUI help locate the target and confirm it is the correct target with a cross check of the map.

Overall, all of these environment information elements give the PUI enough data for the PUI to understand what is happening, when it is happening, and where it is happening, so they can execute the CAS procedures correctly. The next step is to check if the pilot comprehends these details and truly knows what is going on around them and what will happen in the near future (Endsley 2001, 4). To accomplish this we must create a method for the pilot to express their perception and comprehension of the battlefield and then develop a means to measure how accurate the pilot's views are.

C. HOW TO ASSESS AND MEASURE SA

At some point after receiving the environmental information to build SA, it is necessary to check how good the PUI's SA is. To evaluate SA effectively several things must be determined. The first is to determine the set of questions that the subjects should be asked to properly evaluate their SA. Secondly, the format to ask the questions and finally, the timing to ask those questions need to be determined.

The points in time when questions should be asked are based on the goal based task analysis (Endsley 2000a, 134). According to Endsley, the questions need to test the spatial and time awareness and the analytical capability of the subject. Those questions should query aspects of the pilot's perception or comprehension of the environment, and the information the pilot submits as they pertain directly to the goal or subgoal of the task. Questions that will be asked need to ensure the pilot can accurately place all friendly and enemy entities at their correct location on a map to demonstrate spatial comprehension. The pilot will be asked about the timing of artillery firing, aviation attacks, and the order of events on the battlefield. The questions are structured to reveal what the PUI comprehends about the entire battle space and to ensure that he (she) does not have tunnel vision on only one aspect, which is a frequent pitfall of new pilots. Currently, IPs commonly ask these questions during "chalk talks" and "walk throughs," so these questions are of the type that SMEs would use.

The way in which questions should be asked to best evaluate pilot's SA is the next area that must be addressed. Endsley lists several types of measurements for SA (Endsley 1988, 792). There are measures that evaluate the subject's perceptions directly such as questionnaires or self-assessments and there are indirect measurements such as behavioral and performance assessments. The indirect measure evaluates how well the subject did on a certain task and then infers that this success was due to the level of SA. However, overall success does not necessarily mean it was due to SA, and it

could be attributed to variety of other factors. Due to this understanding, we opted for using a direct measurement (Endsley 2001, 4).

Now that direct measurement has been decided on, the next step is to decide how to do that direct measurement. There are subjective and objective ways of measuring SA (Endsley 1988, 792). One of the easier ways to measure SA directly proposed by Endsley is to ask the subject how they feel about their SA or have an observer rate the subject's SA. This creates a large margin of error. Subjects may think they know more than they do and third person observer can only use the outcome of a situation to determine SA. The subject may have no idea what is going on around them, but succeed on a lucky guess and deceive the observer. The best technique, according to Strater et al. (2001) and Endsley (1988), is to use objective questioning to evaluate SA.

The question format is the next item that must be decided. Two formats are proposed for use in this trainer: one which users must select the correct answer from a list of possible answers, commonly referred to as multiple choice, and questions where the user inputs a unique answer like fill in the blank or short answer. The selection type question is better for measuring SA. These types of questions are easily measured because the questions have a single correct answer and can be statistically analyzed easily. Also, multiple choice questions should be quicker for the user to answer than the one requiring explanation and longer input. Multiple choice questions can be kept objective as well.

Deciding on the points in time when questions are to be asked is one of the last items to address. The Situation Awareness Global Assessment Technique (SAGAT) developed by Mica Endsley provides excellent guidance on how and when to ask SA evaluating questions during training (Endsley 1988, 789). Many evaluations are set up to ask questions at the completion of training, but it is often hard to recall specific details well after their occurrence (Endsley 1988, 793). For dynamic situation awareness queries, we want to capture the subject's comprehension near real time. Endsley's answer is to "freeze" the training to ask the question. For this, the PTT will pause and the question will

appear on the PTT screen. The PUI answers the question with simulation time stopped. Stopping the simulation time prevents the question from interfering with the training scenario and the pilot's comprehension at exactly that time is recorded.

Finally, the results of the PUI's answers are collected and recorded so an IP can review them and evaluate the PUI's performance. This record needs to contain sufficient information and be easily readable by the instructor if it is to be effective. The output of the PUI's performance contains the following information for each question: the question number, the PUI's answer, the correct answer, and how long it took the PUI to answer the question. The output also presents a composite score based on the total number of questions correct. This information provides the instructor with enough information to see where the PUI is succeeding or struggling with comprehension of the CAS environment. The record should also print out in a format that is easily readable by the instructor.

D. CHAPTER SUMMARY

In this chapter, we determined how to use the PTT to present elements of the CAS environment and develop situation awareness in CAS for the new pilot. The text also discussed the best ways in which pilot's SA could be evaluated, format in which that is done, and the timing of those queries.

IV. TASK ANALYSIS

A. INTRODUCTION

The CAS operator is required to assimilate and sort a large amount of information, and it makes it difficult for the operator to effectively organize that data to gain high level of situation awareness. To make the data manageable, having a systematic and integrated process is very much needed. Task analysis helps understand many elements specific for the task of interest, including the environment and conditions in which the task is executed, and the goals that need to be achieved by the user. Task analysis breaks down the steps of the task, and how an individual executes each step specifying the conditions and level of mastery needed to achieve task goals (the same approach applies if more than one user is engaged on given task). Once each step is identified and a measurable performance specified, the supporting system architecture and necessary teaching methods can be developed.

B. EXECUTION

Two tasks were analyzed in support of this research effort. Helicopter pilots conduct each of the tasks, one pilot is an instructor (IP) and the other is a trainee (PUI). The PUI is a novice operator while the IP is an expert operator in the Close Air Support domain. The PUI is qualified to fly and operate the aircraft, but has had only limited exposure to tactical employment like CAS. The IP has reached the expert level in CAS operations through several years of dedicated training and dozens of CAS training and/or real world CAS missions. Also, the IP has completed an additional training syllabus teaching him (her) how to instruct CAS training.

Many entities are involved in actual CAS operations. They all have discreet tasks they must accomplish to execute the CAS mission. For this part task trainer, we will focus on the tasks required by the PUI and IP: the creation and execution of the scenario to train situation awareness. The IP's tasks are

conducted in the same manner as actual CAS pre-mission planning would be done. This planning usually happens inside a unit's planning rooms while using mission planning tools like maps and diagrams of the battle area. The IP's responsibility is to create the CAS environment for the PUI. In a CAS mission, training or real world, the PUI would be in the cockpit of the aircraft managing the information required to gain SA by observing the battlespace environment, listening to radio communications, and operating the aircraft systems. This would be a very dynamic environment even for the simple introductory missions. Our intent is to create a CAS environment with few distractors while maintaining the time constraints and environmental information required for CAS. This is so the PUI can focus on the essential tasks required to gain SA using the simulated elements of the PTT.

C. PREVIOUS CAS TASK ANALYSIS WORKS

Attig (2106) completed a formal task analysis focused on the pilot's tasks required to conduct CAS in his Master's thesis. His task analysis used the AH-1W T&R manual and was presented in the behavioral task analysis form with individual observable actions (Clark and Estes 1996, 403). Each task's goals began with a certain initial state, which precipitated a specific action by the pilot. This produces a particular results and then on to the next sequential task. For instance, prior to arriving at the objective area (basically the battle area where the kinetic portions of CAS take place) the pilot needs to tune to a certain radio frequency, contact the terminal controller, and expect to receive instruction of where to go and await further CAS instructions (Attig 2016).

Conversely, the task analysis for situation awareness needs to be a cognitive task analysis because SA is mental process requiring cognitive abilities. Clark and Estes (1996) stated that cognitive abilities include items such as pattern recognition, perception, attention, and decision making, all of which have been directly associated with situation awareness (403). As stated earlier, Endsley (2001) also believes SA task analysis is best served using a "goal-

directed" cognitive task analysis to capture the dynamic nature of SA. (8) This differs from the behavioral task analysis in that each goal oriented task is supported by a decision informed by the operator's three levels of SA, perception, comprehension, and projection instead of following a sequential procedure.

D. COGNITIVE TASK ANALYSIS FOR CAS SA

The task analysis for this study will be divided into two separate cognitive task analyses: one task analysis for the IP's task of building of the CAS scenario, and one for the PUI's task of conducting the CAS scenario. Building the CAS scenario for the trainer requires a cognitive task analysis because the IP has to construct the scenario using complicated problem-solving skills rather than simply following step-by-step instructions. According to the *Combat Aircraft Fundamentals UH-1* guidelines, the IP builds the CAS scenario very similarly to the way a pilot plans a CAS mission. (Department of the Navy 2013). The IP is an expert in CAS and knows how to build the scenario; the IP's extensive experience in planning and executing CAS missions is extremely important in this process. The IP begins by developing the big picture of the battlespace environment, and then continues with the rest of the specific steps aimed at building the scenario.

1. CAS Scenario Builder Cognitive Task Analysis

The scenario builder's top level goal is to create the CAS scenario. The IP starts, as stated earlier, by developing the big picture of the battlefield first. In military verbiage the big picture is often termed "big blue arrows," signifying large blue arrows depicted on military maps that represent friendly troop movements across the battlefield. This "big blue arrow" picture is the overall scheme of maneuver of both the friendly and enemy units. For example, the situation may be the friendly side attacking to seize a key road intersection with the enemy defending it or the enemy trying to capture an important industrial city and the friendlies holding the high ground outside the city. The scenario starts at this

level: the friendly ground unit's scheme of maneuver and fire support plan as well as the enemy disposition determines how the CAS mission will be conducted (Department of the Navy 2013). These will be the major subtasks in the task analysis. Once these items are determined, further subtasks must be completed to create the scenario. The CAS joint publication describes battle tracking as constructing the battle environment in an accurate manner (CJCS 2009, V-2). The elements of battle tracking comprise the essential elements the IP needs to include in the scenario build. Those include

1. Fire Support Control Measures (FSCMs) and Airspace Coordination Measures (ACMs)
2. Friendly Unit Location
3. Artillery Location, Gun Target Lines (GTLs) and targets
4. Target Location
5. Orders like CAS attack briefs
6. Communications

Integration of these components allows PTT operator to create a CAS scenario for the PUI. We have limited the tasks and conditions of CAS operations supported in the PTT: this includes only day, Type 1 CAS requirements for non-precision guided ordnance. Additionally it does not cover any aircraft, ordnance, or targeting specifics. Table 2 provides details of the complete scenario building task analysis.

Table 2. IP Cognitive Task Analysis for CAS Scenario Creation.

1. Create CAS scenario.
 - 1.1. Determine friendly and enemy scheme of maneuver in terms of each side's objectives during the scenario.
 - 1.1.1. Determine location of objective area based on terrain.
 - 1.1.2. Determine Enemy disposition.
 - 1.1.3. Determine Friendly disposition.
 - 1.2. Build objective area
 - 1.2.1. Determine and place target location.
 - 1.2.2. Determine and place threat location.
 - 1.2.3. Determine friendly location.
 - 1.2.4. Determine and place Artillery Gun Positions (GPs).
 - 1.2.5. Determine and place Artillery at desired GP.
 - 1.3. Create Fire Support Plan in support of Friendly scheme of maneuver.
 - 1.3.1. Create FSCMs and ACAs with regard to Friendly and Enemy positions.
 - 1.3.1.1. Place Battle Positions (BPs).
 - 1.3.1.2. Place Holding Areas (HAs).
 - 1.3.2. Create aircraft route to CAS objective area.
 - 1.3.2.1. Select route checkpoints.
 - 1.3.3. Create 9 Line CAS attack brief.
 - 1.3.3.1. Determine and select BP.
 - 1.3.3.2. Determine and select HA.
 - 1.3.3.3. Determine and select aircraft Egress.

2. CAS Scenario Execution for Situation Awareness Cognitive Task Analysis

The second part of our task analysis captures the PUI task of using the PTT to execute CAS mission (scenario). Most of the pilot's procedural tasks described in Attig's (2016) task analysis are conducted automatically by the PTT. Still, the PUI is expected to understand these steps and to know when and where they should occur. The PUI is also responsible for all of the information provided in these steps; PUI needs to retain it for use during the scenario as that same information drives the PUI's decision making process. Much of this information will be passed via simulated radio communications during the scenario.

The focus of this task analysis is on the cognitive tasks required by the pilot to attain and maintain situation awareness. Each of the steps involves the PUI understanding of the elements in the aforementioned CAS joint publication's tactical risk assessment (CJCS 2009, V-18). This task analysis limits its elements to those required for initial CAS training and elements that are present in the CAS PTT: CAS check-in, CAS situation update, CAS 9 Line attack brief with supporting arms and threat remarks, and time-on-target (TOT) for Type 1 attack. As commented earlier, the PTT and corresponding task analysis do not cover the full realm of CAS possibilities. Also, more than one task or subtask may be active at the same time and different tasks may share subtasks. Table 3 presents all details of the CAS Execution for SA cognitive task analysis.

Table 3. CAS Execution for SA Cognitive Task Analysis.

1.	Perceive and comprehend the CAS battlespace
1.1.	Determine how friendly elements affect the CAS attack.
1.1.1.	Determine how to support friendly ground units and avoid fratricide.
1.1.1.1.	Know the distance of the friendly maneuver element from the target.
1.1.1.2.	Compute what final attack headings (FAHs) are usable from the selected BP.
1.1.1.3.	Know effects distance of CAS fires.
1.1.1.4.	Know target location.
1.1.1.5.	Know aircraft location.
1.1.2.	Determine how supporting arms affect the CAS attack?
1.1.2.1.	Know artillery location.
1.1.2.2.	Know artillery GTL and what if any ACMs or FAHs it crosses.
1.1.2.3.	Know when and where artillery is firing suppression.
1.1.2.4.	Know when artillery is marking the target.
1.1.2.5.	Know aircraft location.
1.2.	Determine how enemy elements affect the CAS attack.
1.2.1.	Determine how the target impacts the CAS attack.
1.2.1.1.	Know target location.
1.2.1.2.	Know target type.
1.2.2.	Determine how and where the air threat impacts the CAS attack.
1.2.2.1.	Know threat location.
1.2.2.2.	Know threat range.
1.2.2.3.	Know aircraft location.

- 1.2.3. Resolve how threat will be mitigated during attack.
- 1.3. Determine CAS attack from selected ACMs is tactically sound.
 - 1.3.1. Know attack heading from BP to target.
 - 1.3.2. Ensure that FAHs point toward the target and do not encroach on GTL or head toward friendlies.
 - 1.3.3. Ensure that target mark is visible on ingress from BP to target.
 - 1.3.4. Ensure that route of flight avoids threat and GTL.
- 1.4. Determine how time affects the CAS attack.
 - 1.4.1. Know when you should receive routing and safety of flight, situation update, CAS attack brief, remarks and restrictions, TOT, and clearance.
 - 1.4.2. Determine when suppression will be impacting target.
 - 1.4.2.1. Know TOT.
 - 1.4.3. Determine when target mark will be visible.
 - 1.4.3.1. Know TOT.
 - 1.4.4. Determine time to move from HA to BP to meet TOT.
 - 1.4.4.1 Know current time.
 - 1.4.4.2. Know TOT.

E. CHAPTER SUMMARY

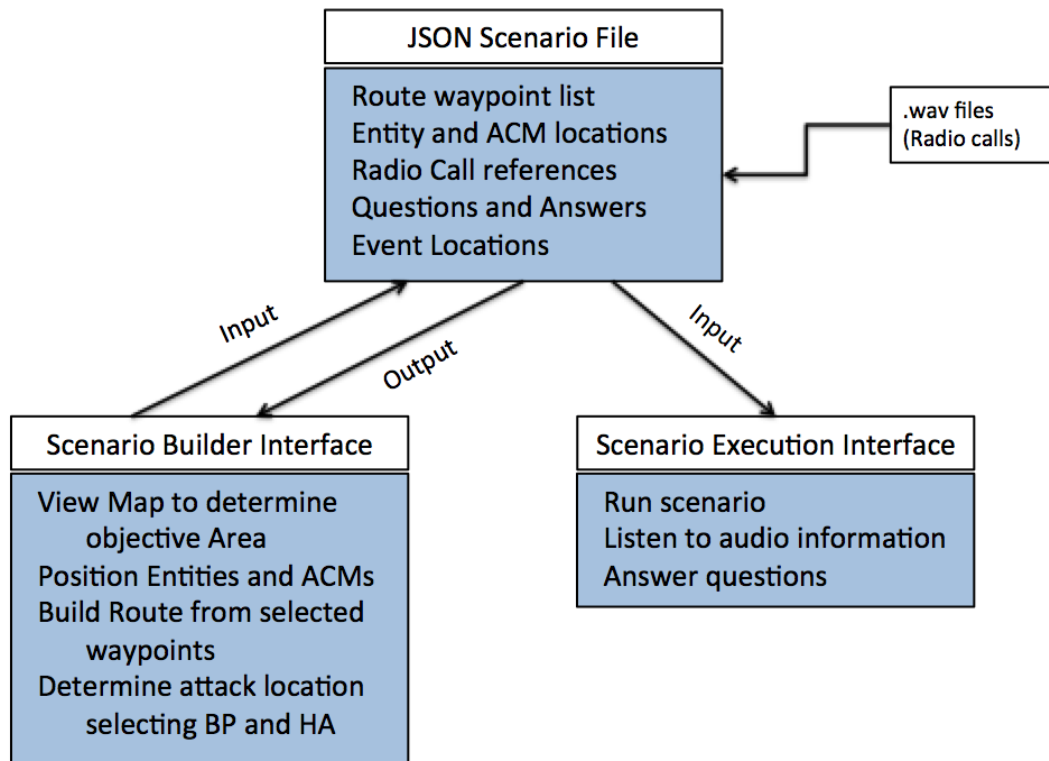
This chapter presented the results of two cognitive task analyses in support of PTT for CAS situation awareness; the analysis augmented previously executed behavior task analysis for CAS execution (Attig 2016). The first cognitive task analysis was focused on IP's creation of the CAS SA scenario, and the second cognitive task analysis was focused on PUI's execution of the CAS SA scenario.

V. SYSTEM DESCRIPTION

A. FRAMEWORK

The HMLA CAS PTT for SA was created using a part task trainer proof of concept model designed by Attig (2016). Attig used the Unity game engine to develop all necessary elements of his proof of concept PTT. We used the same framework architecture to support IP's CAS scenario building and PUI's CAS scenario execution. The IP builds the scenario using the capabilities of the IP interface; that scenario is then exported as a JavaScript Object Notation (JSON) file. The JSON file is imported and run using the PUI interface. Figure 1 depicts the elements of system architecture including data flows and user interaction.

Figure 1. HMLA CAS PTT Architecture. Adapted from Attig (2016).



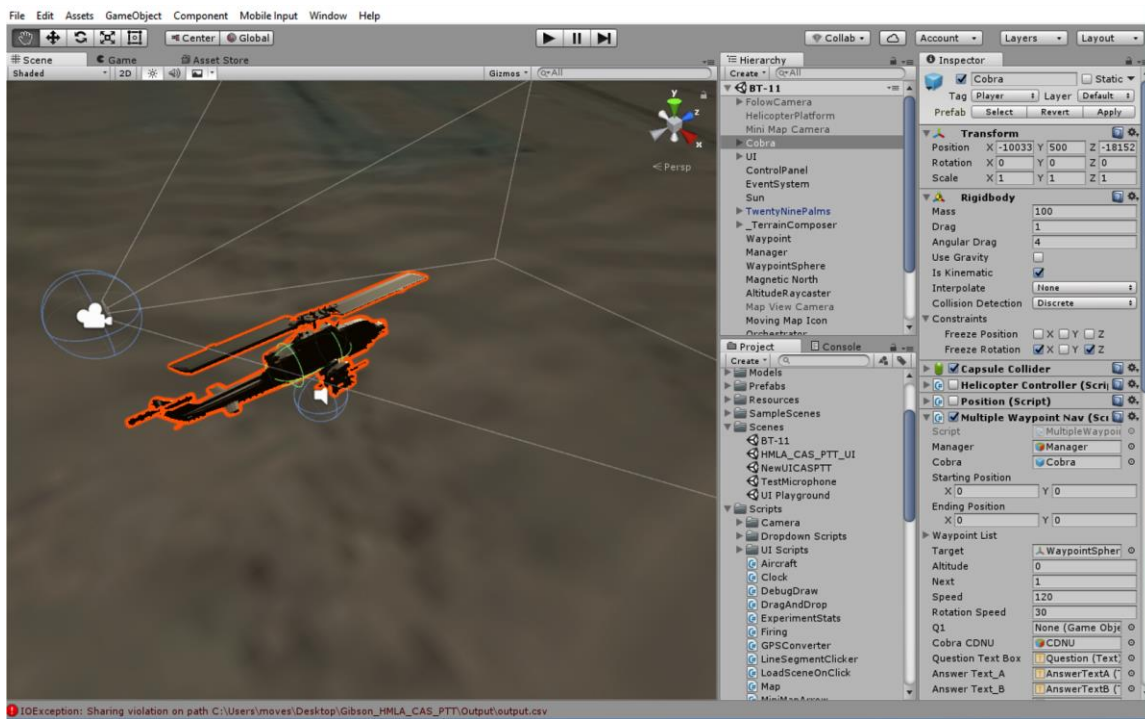
Some elements from Attig's (2016) master's thesis project were used in our trainer. They included the terrain, 3D model of the Cobra helicopter, the question and answer interface, and the system to convert latitude and longitude coordinates to Unity coordinates. The rest of the system needed to support the specifics of SA elements was designed and implemented by the author of this thesis. Those efforts focused on adding the additional entities, events, and information required to create the CAS battlefield and to create a situation awareness enriching environment.

B. DEVELOPMENT AND PROGRAMMING ENVIRONMENT

The Unity game engine was chosen for the CAS PTT for several reasons. First, Unity's universal capabilities are a large reason it was selected. Unity provides the flexibility to run on a wide range of platforms including personal computers, tablet computers, and smart phones on a multitude of different operating systems. The Unity software can run locally as an independent (stand-alone) application or be web based and run from the cloud. Also, Unity is compatible with a large array of audio and video files, and Unity has a large library of 3D models and software development kits available for use.

Applications can be started quickly in Unity due to the extensive tutorials provided by Unity and the intuitive game development environment. Projects can be developed in Unity using the graphic editor interface, via scripting, or a combination of both. See Figure 2 to view the Unity graphic editor. Unity comes with the MonoDevelop integrated development environment (IDE) to write scripts and compatible with many other IDEs. For the CAS PTT we used a combination of the graphical editor and scripting with MonoDevelop. The graphical editor was used for building the CAS PTT graphic user interface (GUI) and visual 3D models. Scripting in MonoDevelop created all the CAS PTT behaviors and calculations.

Figure 2. Unity Graphic Editor.



C. INTERFACE FOR SCENARIO BUILDER (IP INTERFACE)

To begin creating the complete CAS scenario we needed to add critical physical elements and their associated behaviors to the scenario. These elements include the target, the friendlies, the artillery, and a threat. These entities need to be placed in the virtual environment at specific locations by the IP. To do this, the IP needed an effective way to insert these entities at exact geographic coordinates and then see a visualization to ensure the placement was correct. We decided to use a map system to allow the IP to view the placement of the battlefield entities' locations – the interactive style used for this part of the interface was "direct manipulation." The IP positions the entities at locations on a map and these positions translate directly to corresponding locations on the 3D terrain that the PUI views. To position the entities precisely, we decided to utilize a gridded 2D map, as it is the most common spatial reference representation used by pilots in CAS missions. Since the terrain used

in the CAS scene represented the Marine Corps Air Ground Combat Center (MCAGCC) at Twentynine Palms, California, the Twentynine Palms Military Installation Map (MIM) was used to depict that same area in the IP interface. (National Geospatial-Intelligence Agency (NGA) 2009). The 2D Twentynine Palms MIM is a much lower resolution than the terrain at the 1:100,000 scale, meaning 1 cm of distance on the map represents 1 km on the real ground. This is sufficient detail to depict the entities in order to reference their location while the 3D terrain is a much higher resolution to accurately depict the terrain detail for visualization in the scenario execution. The entities were then represented on the map with military operational graphic icons. This allowed the IP to know the exact real world coordinates for every entity.

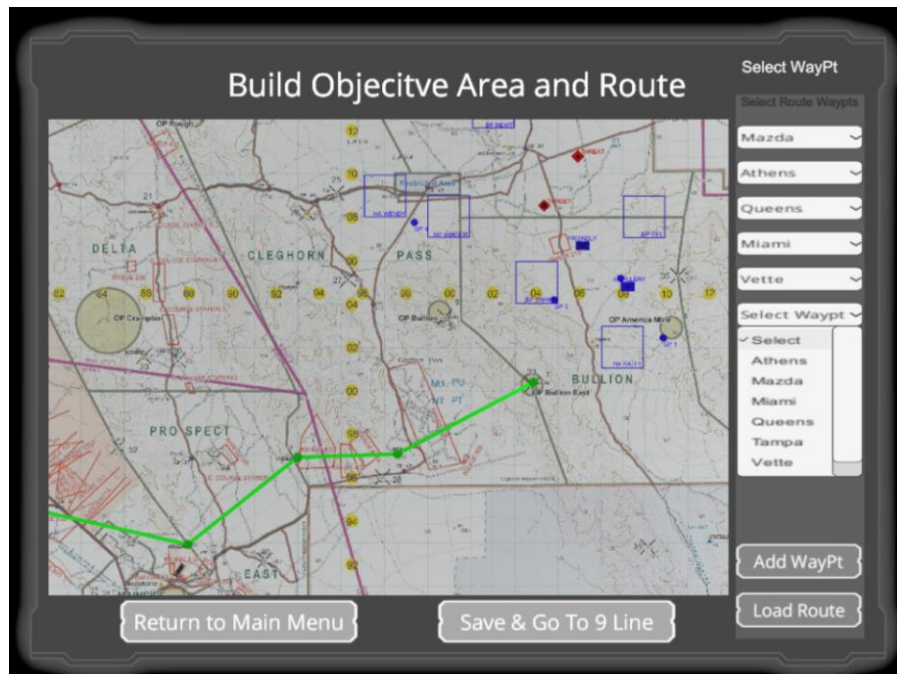
The technical skills of IPs may differ greatly. Some may have extensive computer skills, and some may have very basic or limited computer skills. To support IPs with extensive CAS skills but who may have basic or limited computer skills, it was decided to further streamline and simplify this IP interface, and make sure that all IPs can create CAS scenarios in a timely manner. The use of the map in the IP's interface was the first step in that direction. The next step was to create the CAS situation and attack brief that would drive the scenario. To do this we made use of the traditional 9 Line CAS attack brief complete with remarks - this brief provides the most familiar and succinct format to generate the CAS scenario. It contains all of the essential elements and their specifics: the target, friendlies, artillery, and threat. CAS scenarios can be very complicated and require more information, but the 9 Line CAS attack brief and map depicting the essential entities locations are suitable for the basic CAS mission used to train a new pilot. Using the capabilities of the 9 Line and the map, an IP could now easily create the entire CAS scenario in IP interface.

Originally, we designed the interface so the IP would need to input the coordinates for the entities, ACMs, route waypoints and the CAS 9 Line information by tying in each location. After completing the input, the IP would load them to the map and see the location of each entity. Our initial tests showed

that this process was time consuming. Also, it was easy to type an incorrect number and not realize it until the all data entry is complete and when viewing the map. To improve this capability, it was decided to make the scenario generation similar to real CAS planning and make sure that this process is as intuitive as possible.

In actual CAS planning, once the ACM and entity locations are known, they are plotted on the map. To mimic this we forgo inputting the entities and ACMs' coordinates manually, and instead allowed the IP direct manipulation of the icons—IP can drag and drop the objects representing the same entities to the correct locations on the map. The IP gets immediate visual feedback about the location and Unity scripts then calculate the coordinates of all objects. Similarly, the route waypoints are selected instead of entering their coordinates (numbers) manually. Route waypoints are usually predetermined checkpoints stored on a list. Most likely they are selected during a planning stage that helps create a route to get the aircraft to the objective area quickly while avoiding other air traffic and threats. The interface was changed to accept a list of waypoints from the commonly used and easily compatible comma-separated value (CSV) file. The CSV file contains information about each checkpoint name, its latitude and longitude common to most readily available waypoint lists. The waypoints populate a drop down selection box in the interface and the IP selects the waypoints as desired. The selected waypoints, entity locations, and ACMs then generate the latitude and longitude coordinates for the JSON file automatically. Each waypoint and the route are displayed on the map as the IP selects them. Figure 3 shows the elements of the graphic interface that enables building CAS scenario objective area.

Figure 3. CAS Objective Area Builder Map Interface.



The 9 Line builder interface displays the 9 Line CAS attack brief to the IP. Originally, the 9 Line builder required the IP to enter a large amount of information via drop down selections and type text inputs. The IP needed to reference the location of the entities and ACMs from the map and make the entries that consumed a lot of time and increased the opportunity for error. After review and the implementation of the drag and drop entities and ACMs, we decided to translate the location coordinates of the objects on the map into numerical data and use that to auto-populate select elements of 9 Line form. Upon activating the 9 Line builder, it now displayed the target, threat, friendly, and artillery information generated by the objective area builder. Selecting the BP for the CAS aircraft to attack from the drop down list, the system calculates the remaining information for the attack brief including the heading and distance from the selected BP to the target from the location data. The IP then selects the aircraft egress direction determining the direction of the aircraft pull off from the target, and selects the HA to use. This information is then saved and exported

via the CSV file so that it can be used in the CAS execution portion (PUI interface). Figure 4 shows the design of the CAS 9 Line builder interface. After building the scenario, the CSV is loaded in the CAS execution portion via PUI interface. The JSON file method is used so IPs can build multiple scenarios and save each as a separate file. This helps create a library of scenarios for the PUI to train on.

Figure 4. CAS 9 Line Builder Interface.

9 Line

1. IP / BP BP Snake
2. Heading 003
3. Distance (meters) 3700
4. Location Lat / Long (HH.MMMM)
 Lat N 34.41468 Long W 115.8661
5. Target Description Truck
6. Target Elevation (ft MSL) 1230
7. Type Mark Smoke
8. Location of Friendlies
 Direction South Distance (meters) 2600
9. Egress _to_

Remarks & Restrictions

Final Attack Heading 343 _to_ 023

Threat : Type ZSU-23-4

Threat : Direction North & Distance (m) 2800

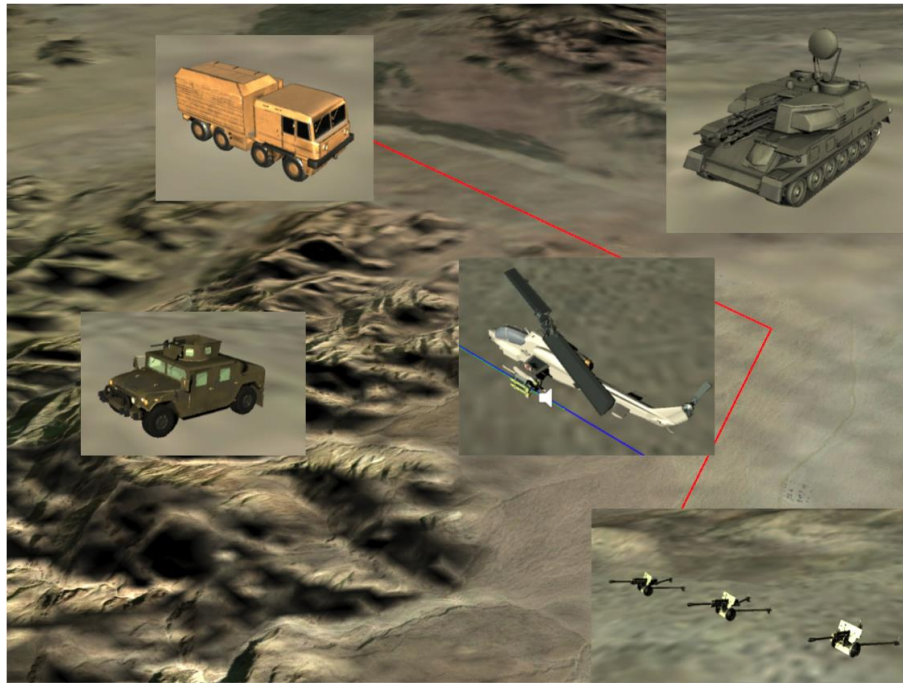
Arty Gun Target Line 352 ,Continuous Suppression

D. CAS SCENARIO EXECUTION INTERFACE (PUI INTERFACE)

While the CAS execution scenario looks similar to the one in Attig's (2016) work, several changes were made to this interface to make sure that scenario provides a better opportunity for acquiring situation awareness. The first and most noticeable change to the scene is the addition of the friendly and enemy units. Three-dimensional models from the Unity asset store representing the target, threat, artillery, and friendly maneuver element are inserted on the terrain for visual cueing. The appropriate model spawns at the location corresponding to

where the IP placed during the scenario building. The 3D models add to the realism of the CAS scenario. The PUI can now see visible representations of those objects. Figure 5 depicts 3D models of all possible entities.

Figure 5. 3D Modes in CAS Execution Scenario.



We created effects to simulate the entities interacting on the battlefield environment. For example, the helicopter engagement sequence on the target, the artillery firing threat suppression, and the target mark are visually simulated events. Also, we also simulate the helicopter firing the rockets and the artillery muzzles flash when firing to increase the visual realism of the training environment and improve overall user experience. Flashes and dust clouds simulate the artillery suppression impacts on the enemy air threat, and a simulated explosion shows the destruction of the target. Figure 6 shows some of those visual effects.

Figure 6. Scene with Added Visual Effects.



To further enhance the visual realism of the training environment, we changed the helicopter flight path from a constant altitude to a path that follows the contours of the terrain. This flight regime is more authentic to the actual flight path of a helicopter that performs CAS in this threat level environment. The lower altitude and terrain conformance restricts the pilot's line of sight distance and increases the pilot's dependency on radio communications to provide SA details. We accomplished this by raycasting along the flight path to derive a height of the helicopter above terrain altitude. Other elements that were added to enable SA stimulus included the capability for the pilot to pivot the camera view, which simulated head turning of the pilot, and allow for independent view of the virtual environment.

Also, we added several SA building tools that the pilot would normally have in the real cockpit. A digital clock was added to keep track of mission timing and ensure meeting the TOT. A compass with a magnetic heading indicator was also added to inform the PUI what direction he (she) is going. This allows the

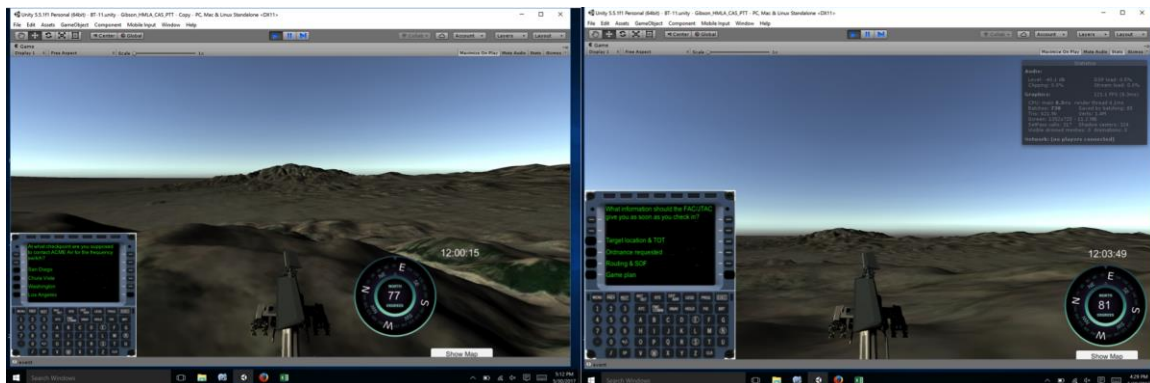
pilot to reference the aircraft heading as it approaches the target, and ensure that the aircraft is within the bounds of the authorized final attack headings (FAH). These directional heading restrictions given by the terminal controller are to guarantee the aircraft only shoots when pointed in a safe direction and it is very important for the pilot to know that he or she is within the limits. Every pilot always has a map in the cockpit, so the same map that is used by the IP to help create CAS scenario is included in this interface as well. The PUI is able to switch the map on and off as needed. The map can be used to correlate the PUI's position above the virtual terrain. Additionally, a moving icon representing the helicopter's position is available in current moving map displays in modern aircraft. The PUI's map is also designed to contain the same ACMs as the IP map; the only difference that we introduced was that the entities are not initially placed at the correct locations. During the course of CAS scenario, the PUI will receive the locations of these entities via radio communication and he (she) is requested to drag the entity icons to the correct spot on the map. This allows testing PUIs situation awareness in context of the given scenario. Figure 7 shows PUI interface with the cockpit SA builders.

To improve the SA questions-and-answers experience, we added questions that require PUI to drag and drop the entities to their corresponding locations on the map. PUIs are graded on their ability to place the entity icons at the correct location (the information about those locations is passed in the terminal controller's situation update and attack brief.) Other questions are used to evaluate the PUI's SA. They consist of multiple choice questions placed in a communications / data unit (CDU), depicted in the lower left corner on Figure 7. During the simulation, the CDU pop-ups in the lower left corner and displays SA questions that the IP created. The text font size in initial design of CDU was too small to be easily read, and the touch screen buttons on the CDU were too small for larger fingers to activate quickly on the first tap. We decided to increase the overall size of the CDU interface and alleviate those problems. Figure 8 shows changes that were made with design of CDU.

Figure 7. CAS Execution Scenario Cockpit SA Builders.
Adapted from Attig (2016).



Figure 8. Increased Size of Question and Answer Interface.
Adapted from Attig (2016).



The PUI's answers to the questions are recorded to another CSV file at the end of the training session. This CSV output file contains the ID of each question, the time stamp, the PUI's response to that question, the correct response, the time it took the PUI to answer each question and the PUI's overall

score. All of this is useful when evaluating the PUI's performance and determining the focus areas for future training.

E. AUDIO PRODUCTION

Much of the SA information the PUI receives is audio. This SA building audio is almost exclusively in the format of simulated radio communications in the PTT. The IP records a set of radio communications during the scenario development. For the demo scenario, each radio call was recorded individually using the Microsoft Surface Pro and Audacity audio recording and editing software. The tablet platform was used for the demo recording because it is similar to the platform available to the IP. Audacity is free, open source software and works on most common computer operating systems, and we used it to modify and manipulate voice recordings. This allows IP to simulate as if several different people (voices) were used in production, thus enhancing the realism of the CAS scenario where typically multiple agencies would communicate with PUI during the mission.

Once each radio communication is recorded, the individual recorded audio files are inserted into the scenario. Each audio file is associated with specific location along the route of flight for the simulated aircraft. The audio files are linked to this specific location, and when JSON file is imported Unity creates an event that triggers the radio call. When the aircraft reaches a predetermined location on the flight route it activates the trigger and plays the audio. The PUI is expected to remember or record the information passed in the radio communication, and update his (her) SA accordingly.

Ambient helicopter rotor sound was also added for realism, and an effort was made not to create interference with the radio communications. Our intent was that PUI would easily understand the audio, process all information offered through the interface to enhance his (her) SA, and be able to provide correct answers when tested through the interface.

F. CHAPTER SUMMARY

In this chapter we detailed the creation of the IP CAS scenario builder interface and the PUI CAS scenario execution interface, and explained the capabilities that each interface.

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VI. FEASIBILITY TESTING AND USER STUDY

A. INTRODUCTION

This chapter reviews the feasibility of the part task trainer as a training aid and comments on the design of the future usability study. The goal of feasibility study was to provide an initial assessment of the CAS PTT and its technical capabilities. The aim was to determine if the current hardware and software configuration could offer capabilities needed for training CAS operations by a pilot. A formal user study was designed to acquire valuable feedback on the usability of the PTT's interfaces and to gather information for its future improvements.

B. FEASIBILITY TESTING

1. Visuals

The trainer provides an instantaneous sixty-degree field of view of the battlespace virtual environment. This is less than the normal field of view (FOV) for full aircraft simulators, but allowing a user to rotate the camera view and observe a much larger portion of battlespace compensates for this. This is similar to the Army's Dismounted Soldier Training System that provides an instantaneous sixty degree FOV augmented by the ability to move the FOV direction to increase the virtual environment area observed (Bink et al. 2015, 3).

The terrain graphics and other 3D models render completely throughout the simulation. The graphics refresh at a sufficient rate throughout the simulation: the lowest rate observed was 76 frames per second (FPS) when the moving map segment of PUI interface was open. The average refresh was between the mid-80 to mid-90 FPS throughout the simulation. All of these are above the industry accepted minimum of 60 FPS.

2. Audio

Each radio call is audible and clear. Audacity's sound editing function provides an appropriate amount of static noise to sound like an actual radio transmission. The static noise does not interfere with the clarity of the radio dictation, which is desired effect. The sound editing also makes each agency sound like different voices even though the same person recorded most of the radio calls.

3. User Interface

The user interface responded without error to all mouse inputs. The touch screen responded well with the only issue on the CDU interface. Occasionally, the initial touch did not register and the user was required to touch the screen a second time to activate the answer touch button. Multiple tests showed that button responded on the second touch each time. Increasing the CDU button size reduced the number of second touches required, but it did not eliminate them entirely. The first time the CDU pops up on the screen it still requires a second touch to register. The touch screen works on the first touch all other times. We believe this issue to be a bug in our Unity code.

C. DESIGN OF USABILITY STUDY

The intent of the user study is to determine usability of IP and PUI interfaces; this includes efficiency, effectiveness and user satisfaction with those interfaces. Our desire was to find out how well the tablet PC and this PTT performed and gather users' opinions about different elements of both interfaces.

Subjects for the study will be selected from the NPS student population; a condition for each person's participation is their previous experience with aviation training systems and close air support operations. Experienced CAS users will likely find any error or omission in the representation of the CAS scenario and provide feedback on the changes required to fix those issues. The study will also

collect information about subjects' aviation and CAS experience. Appendix A details the elements of all questionnaires, including demographics data.

The usability study shall consist of a familiarization with the interface, followed by the session during which subjects will use the scenario builder and then execute the scenario in the role of the PUI. Subjects will provide their feedback on the usefulness and feasibility of the system using a questionnaire after each phase (builder phase and execution phases). Appendices B and C detail elements of both questionnaires.

All of the study's sessions are to be conducted in a computer lab at the NPS Modeling, Simulation, and Virtual Environments (MOVES) Institute. Only the study administrator (a researcher) and the subject will be present in the room. Each session is designed to be video recorded to look for behavioral responses if needed (example: user's posture, use of tablet platform and input modalities during each session). The Microsoft Surface Pro 4 with the touch screen, keyboard and a detached mouse will be used as the PTT platform for each subject.

Each subject's study session will begin by viewing prerecorded instructional video on how to use the CAS PTT scenario builder interface (IP interface) and the execution interface (PUI interface). The training videos were created to ensure a complete and consistent level of familiarization for each subject. After watching the training videos the subject will be asked to build a complete CAS scenario using the IP interface. Each subject built scenario will be from the same template. The template will contain all ACM and entity locations, the route checkpoints, and the 9 Line information to ensure a uniform experience for all subjects (the template will be presented to each subject on a piece of paper.) Each subject shall be given the opportunity to utilize both the mouse and the touch screen for input in building the scenario.

At the completion of building the scenario, the subjects will begin the execution phase of the training. Each subject will be given a sheet of paper and

pen to record in-flight information. The sheet of paper simulates the pilot's kneeboard in the cockpit; they will be allowed to record any information they deem necessary. The scenario is designed to give the subjects a chance to become familiar with the interface and use SA tools before they begin to receive SA information and answer the questions. During the scenario subjects will be asked to use both the mouse and the touch screen to evaluate usability of each input method. The PTT training session will be completed by listening to all of the radio communications and answering the SA questions. PTT will keep information about subjects' performance, and they will not be provided with their score during the session.

Subjects will be able to ask any question or make verbal comments during and after the session. Upon the completion of the study, results of subject's performance will be reviewed with each person. All collected data will be used to determine future improvements to the CAS PTT.

VII. CONCLUSIONS AND FUTURE WORK

A. CONCLUSIONS

During this study, we were able to design and build a tablet-based CAS part task trainer that focuses on training SA. The tablet PC platform using an open software game engine and commercially available 3D models were both low cost easy to use. All essential elements of the CAS environment were replicated and presented capably by the system. Based on this, the tablet PC running game engine software proved to be a feasible training option.

Using the tablet PC to create a compelling CAS environment and user experience was successful too. The tablet provided both visual and audio stimulus to the user. The user received required information via these two modes and was able to answer SA questions. The remodeled user interface allows a scenario to encompass the entire CAS mission, expanding the capability of the original system originally developed by Attig (2016). Also, the new scenario generating interface introduced a virtual map tool, and provided a familiar way for pilots to create scenarios. Expedient graphic based generation of numeric data like coordinates provided a much quicker, intuitive way of setting up the scenarios, including a visual feedback and confirmation to the user.

The system does have its limitations though. The difficulty predominantly lies in time required to create the radio calls and insert the questions at the correct location. This would need to be remedied before the system can meet its true potential. Pilot interaction via PUI interface is limited to answering the questions and repositioning the icons on the screen. We believe that additional decision-making system capabilities and user interactions would greatly enhance user experience. While the questions asked via PUI interface do an adequate job of evaluating the PUI's SA on spatial elements and time driven events, further research must be conducted to determine if the CAS PTT does in fact improve PUI's SA. The results of our user study, once acquired, would provide advices for

addition improvements to the CAS PTT, and create better virtual training environment.

The trainer can undoubtedly serve as augmentation to current training solutions available in this domain - it is well past the time that pilot ground training advances beyond printed publications. This PTT is a promising direction in using commercial off-the-shelf solutions to implement the low cost VR training system for the benefit of Marine Corps aviation. The low cost, easy-to-use and easy-to-field system like this should make sure that it ends up in the hands of all pilots throughout the fleet.

B. FUTURE WORK

The following improvements and additions to the system could be suggested:

1. Improved Radio Communications and Question Entry

Improving the radio call input system would greatly increase the speed of creating scenarios. Currently, radio calls are recorded individually and then placed at the appropriate location in the scenario. This is time consuming and it requires a new set of radio calls for each scenario. Many CAS radio calls are very formulaic and could be easily reused. The shell of common radio calls minus the 9 Line inputs could be preloaded into the system. Inputs into the objective area and 9 Line builder could then generate specifics like heading, BP, and artillery gun target line using a text-to-speech capability.

Increasing the speed of entering the question into the interface is another addition that would speed the creation of scenarios. Currently all questions must be manually typed into the interface or JSON file. Uploading a file of premade questions from a CSV file or having a list of questions to choose from via the interface would reduce time required to build the scenario.

Once these new radio communication and question entry formats were completed, it would be beneficial to have a new method of placing the event

location in the scenario. The exact location the event is determined now, but after placing the radio or question event, the scenario must be ran to ensure that event does not overlap with other events. It would be very helpful to have an appropriate graphical or time display interface that shows the distance along a route where the radio communication is completed or where a question is asked.

2. Increase User Interaction during the Execution of CAS Scenario

The PTT only requires the user to answers questions and reposition icons when SA is evaluated. To take the PTT capability to the next level, the users should make decisions during the training and be tested how well they able to project future events. Some inputs to meet this end would be to ask a user to determine flight path based on events in the scenario. Additionally, the user could be asked to make radio calls. The former would require an additional input, but could be done using either the mouse or touch screen. The latter could be done with the existing microphone on computer platform and speech-to-text software.

3. Usability Study

Getting the input of IP SMEs on the usability of the PTT will provide some immediate feedback on the PTT's usefulness. The appropriateness and quality of the IP and PUI interfaces and the PUI immersive environment and scenario are particular areas that could see either improvement or validation with SME feedback. Ultimately, the SMEs would provide a good barometer on if the PTT is a step in the correct direction and provide inputs to improve immediate shortcomings in the trainer.

4. Transfer of Training Study

A transfer of training study provides insight on the effectiveness of the CAS PTT to train SA techniques. Designing a study to evaluate how PUIs performed during CAS training missions in the flight simulator or aircraft would verify if this CAS PTT is improving PUI's situation awareness. This would also

provide valuable understanding about both the PTT's training scenarios and the PTT medium used to deliver the training. IP's could evaluate how well users of the PTT understood the CAS environment and then made well-informed decisions about PUIs skill remediation and future training.

5. Expanded Mission Capability

There are opportunities to expand mission capability of the CAS PTT. One of them would be to create more complex CAS mission sets by adding additional entities and environmental factors for the PUI to interact with. The addition of a second aircraft in the PUI's flight element would increase the realism of the CAS situation and require the PUI to maintain SA on a virtual wingman. Adding fixed wing or other rotary wing CAS aircraft to the scenario would also increase the complexity and realism because there are frequently more than one CAS flight element in an objective.

Also, due to the flexible nature of the part task trainer other mission sets could be added. The Forward Air Controller (Airborne) (FAC(A)) mission is conducted to support CAS missions and would be a natural addition to the PTT. Once the CAS mission complexity is increased it should be reasonable to add FAC(A) training capability. Assault Support missions like Combat Assault Transport would be another possible addition. Combat Assault Support requirements are very similar to CAS, as they require precise timing, movement, and fires.

6. Integration with other Training Systems

Currently, pilots use the Joint Mission Planning System (JMPS) to plan flight missions. JMPS is a laptop computer based system that contains extensive map and terrain data files. The program's most used functions are for flight routing, fuel usage, and import of ACMs into aircraft computer systems. A JMPS to CAS PTT interface could possibly use the map and terrain data of JMPS to generate the 3D terrain in Unity or incorporate the JMPS ACM and threat data into CAS scenario.

APPENDIX A. DEMOGRAPHIC QUESTIONNAIRE

Thank you for participating in this study. Please fill in the following questionnaire.

1. What is your age? _____
2. What is your sex? _____
3. Current rank? _____
4. How many years do you have on active duty? _____
5. Your primary MOS/Designation: _____
6. How many years of experience flying military aircraft? _____
7. What types of military aircraft have you flown?
 - a. _____
 - b. _____
 - c. _____
8. Number of hours flying military aircraft: _____
9. Was Close Air Support (CAS) a mission set for your aircraft? Check one answer:
 - ☐ NO – go to question 10.
 - ☐ YES – answer the following questions:

If 'Yes':

A: How many years of CAS experience do you have? _____

B: How many CAS mission sorties (training and actual) would you estimate you have flown? Check one answer:

Less than 10	10 - 50	50 - 100	100 - 200	Over 200
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

C: Were you ever an instructor pilot for CAS training? Check one answer:

☐ Yes ☐ No

D: What would rate your CAS proficiency as?

Novice	Advanced Beginner	Competent	Proficient	Expert
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

10. Do you play games?

- ☐ **NO** – go to question 11.
- ☐ **YES** – answer the following questions:

Type of Game (check all that apply)	Devices (Check all answers that apply).	How often? (Check one answer and enter your usage hours .)			
<input type="radio"/> First Person Shooter	I play them on (check <u>all</u> that apply): <input type="radio"/> Computer <input type="radio"/> Game Console <input type="radio"/> Tablet, Ipad <input type="radio"/> Smartphone	<input type="radio"/> Daily Enter # of hours: _____	<input type="radio"/> Weekly Enter # of hours: _____	<input type="radio"/> Monthly Enter # of hours: _____	<input type="radio"/> Rarely
<input type="radio"/> Online multiplayer games	I play them on (check <u>all</u> that apply): <input type="radio"/> Computer <input type="radio"/> Game Console <input type="radio"/> Tablet, Ipad <input type="radio"/> Smartphone	<input type="radio"/> Daily Enter # of hours: _____	<input type="radio"/> Weekly Enter # of hours: _____	<input type="radio"/> Monthly Enter # of hours: _____	<input type="radio"/> Rarely
<input type="radio"/> Adventure, Fantasy, Role Playing Games	I play them on (check <u>all</u> that apply): <input type="radio"/> Computer <input type="radio"/> Game Console <input type="radio"/> Tablet, Ipad <input type="radio"/> Smartphone	<input type="radio"/> Daily Enter # of hours: _____	<input type="radio"/> Weekly Enter # of hours: _____	<input type="radio"/> Monthly Enter # of hours: _____	<input type="radio"/> Rarely
<input type="radio"/> Other games. Enter the genre: _____	I play them on (check <u>all</u> that apply): <input type="radio"/> Computer <input type="radio"/> Game Console <input type="radio"/> Tablet, Ipad <input type="radio"/> Smartphone	<input type="radio"/> Daily Enter # of hours: _____	<input type="radio"/> Weekly Enter # of hours: _____	<input type="radio"/> Monthly Enter # of hours: _____	<input type="radio"/> Rarely

11. Were you required to use training simulations or simulators at any point in your career? Eg -Flight Sims, Part Task Trainers, MTWS, VBS, ISMT, DVTE suite

☐ Yes

☐ No

☐ NO – you are complete with answering questions.

☐ YES – answer the following questions:

A. Enter the names of those simulations, what skills were they used to train, how many hours of training in total, and the date of last usage?

Note*** If you do not remember the name of the simulation, then please enter its closest description instead.

1. Simulation #1: _____

Skills: _____

Total number of hours (approximate): _____

Date of last use (approximate): _____

2. Simulation #2: _____

Skills: _____

Total number of hours (approximate): _____

Date of last use (approximate): _____

3. Simulation #3: _____

Skills: _____

Total number of hours (approximate): _____

Date of last use (approximate): _____

4. Simulation #4: _____

Skills: _____

Total number of hours (approximate): _____

Date of last use (approximate): _____

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APPENDIX B. IP QUESTIONNAIRE

Thank you for participating in this study. Please fill in the following questionnaire.

Think about session that you just completed, and reply to following questions regarding your experience in building the CAS scenario:

1. What was the quality of each visual element of the interface you have just experienced? Check one answer for each characteristic:

Legibility of the text font:

1	2	3	4	5
completely illegible	somewhat illegible	average	somewhat legible	completely legible
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Legibility of the text font:

1	2	3	4	5
completely illegible	somewhat illegible	average	somewhat legible	completely legible
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Contrast (text/foreground and background):

1	2	3	4	5
completely illegible	somewhat illegible	average	somewhat legible	completely legible
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

2. What can you say about the amount of information and guidance provided to you via that interface to help you design CAS scenario? :

1	2	3	4	5
completely insufficient	somewhat insufficient	sufficient	more than sufficient	too much
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

3. Suggest how to improve that guidance:

4. What can you say about the clarity of instructions? :

1	2	3	4	5
very difficult	somewhat difficult	average	somewhat easy	very easy
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

5. Suggest how to improve clarity of instructions:

6. How was the ease of entering information scenario? :

1	2	3	4	5
very difficult	somewhat difficult	average	somewhat easy	very easy
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

7. Suggest how to improve entering information scenario:

8. How useful was it to have 2D Map preview display during scenario building? :

1	2	3	4	5
completely useless	somewhat useless	average	somewhat useful	completely useful
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

9. How was the level of user input into the interface to generate a useful CAS scenario? :

1	2	3	4	5
completely insufficient	somewhat insufficient	sufficient	more than sufficient	too much
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

10. Was there any additional suggestion on how to improve interface that you just tested?

A. _____

B. _____

C. _____

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APPENDIX C. PUI QUESTIONNAIRE

Thank you for participating in this study. Please fill in the following questionnaire.

Think about session that you just completed, and reply to following questions regarding the training scenario:

1. How was the representation of helicopter movement through the battle space?

Check one answer:

1
completely
inaccurate
☐

2
somewhat
inaccurate
☐

3
average
☐

4
somewhat
accurate
☐

5
completely
accurate
☐

2. Between the radio communications and 2D map chip, how was the quantity of information that you were provided with to understand the situation, particularly the battle space and the CAS mission details? Check one answer:

1
completely
insufficient
☐

2
somewhat
insufficient
☐

3
average
☐

4
somewhat
sufficient
☐

5
completely
sufficient
☐

3. How was the 2D Map chip? Check one answer:

1
not helpful
at all
☐

2
somewhat
not helpful
☐

3
average
☐

4
somewhat
helpful
☐

5
very helpful
☐

4. Please evaluate the appearance of Comm/Nav/Data display that was used to receive info and to answer the questions (shown in lower left corner of your display during the session). Check one answer for each characteristic:

Legibility of the text font:

1
completely
illegible
☐

2
somewhat
illegible
☐

3
average
☐

4
somewhat
legible
☐

5
completely
legible
☐

Legibility of the text font:

1	2	3	4	5
completely illegible	somewhat illegible	average	somewhat legible	completely legible
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Contrast (text/foreground and background):

1	2	3	4	5
completely illegible	somewhat illegible	average	somewhat legible	completely legible
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Ease of answering questions using mouse click:

1	2	3	4	5
very difficult	somewhat difficult	average	somewhat easy	very easy
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Ease of answering questions by tapping on a touchscreen:

1	2	3	4	5
very difficult	somewhat difficult	average	somewhat easy	very easy
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

5. What method did you prefer to enter your answers: using a mouse (mouse click) or tap on a touchscreen? Check one answer only.

Mouse click	Tap on the touchscreen
<input type="checkbox"/>	<input type="checkbox"/>

6. Evaluate the radio communications. Check one answer for each characteristic:

Radio calls were presented at the appropriate time for the mission:

1	2	3	4	5
never	rarely	neutral	mostly	always
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Radio communications were loud and clear:

1	2	3	4	5
never	rarely	neutral	mostly	always
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

The scenario radio calls contained all required CAS radio communications:

- | | | | | |
|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| 1 | 2 | 3 | 4 | 5 |
| never | rarely | neutral | mostly | always |
| <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

7. Evaluate the camera view rotation capability. Check one answer for each characteristic:

The ability to rotate or move the camera view was beneficial for the mission:

- | | | | | |
|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| 1 | 2 | 3 | 4 | 5 |
| not helpful
at all | somewhat
not helpful | average | somewhat
helpful | very helpful |
| <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

How often did you use the camera view rotation feature:

- | | | | |
|--------------------------|--------------------------|--------------------------|--------------------------|
| 1 | 2 | 3 | 4 |
| never | seldom | occasionally | frequently |
| <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

8. Evaluate the compass heading indicator. Check one answer for each characteristic:

The compass was helpful for orientation during the training session:

- | | |
|--------------------------|--------------------------|
| Yes | No |
| <input type="checkbox"/> | <input type="checkbox"/> |

How many times did you reference the compass to know aircraft heading:

- | | | | | |
|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| 1 | 2 | 3 | 4 | 5 |
| never | once | 2 - 3 times | 4 - 5 times | > 5 times |
| <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

9. Do you have a preference for the type of camera view the trainer uses? Check one answer:

- | | | |
|--------------------------|--------------------------|--------------------------|
| 1 | 2 | 3 |
| 1st Person | 3rd Person | No Preference |
| <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

10. Would you recommend this type of trainer to be used to teach CAS procedures and techniques to enhance situational awareness? Check one answer.

Yes

☐

No

☐

11. What are your top 3 suggestions for changes or improvements to the trainer?

1. _____

2. _____

3. _____

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